

Ecosystem Service Values in Natural Resource Management: A Decision Support Framework

Shane Olsen

BSc; BAppSc (Hons)

A thesis submitted in fulfilment of the requirements for the Degree of
Doctor of Philosophy at the University of Tasmania.

April 2009

Morris
Thesis
OLSEN
PHD
2009

Declaration

This thesis contains no material that has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Shane Olsen 9/4/09

Shane Olsen

This thesis may be made available for loan and limited copying in accordance with the *Copyright Act* 1968.

Shane Olsen 9/4/09

Shane Olsen

Abstract

Mounting evidence indicates that every ecosystem on the planet is showing signs of deterioration and is seriously threatening the ability of nature to provide crucial ecosystem services to human society. Many ecosystem services are in decline due to human ignorance of their value and inadequate social and economic mechanisms to manage them sustainably.

This thesis establishes the basis for greater recognition of ecosystem services in the management of natural resources. This is achieved in three ways. Firstly, the thesis develops a classification of ecosystem services for application to natural resource management issues. The classification overcomes the problems of previous typologies by distinguishing between those services that contribute to other services and the 'end' services themselves. Ecosystem service values can be directly ascribed to provisioning and cultural services. However, the majority of ecological services are of indirect value as they exist primarily to improve and sustain other services.

Secondly, a multi-criteria evaluation (MCE) decision framework is developed to account for changes in ecosystem services resulting from different management scenarios. The MCE process is developed in conjunction with an expert panel, a stakeholder survey, and a cost-effectiveness analysis. The approach involves establishing an ecosystem services conceptual model, developing future management scenarios, and assessing the impact of these scenarios.

Thirdly, a case study is presented using the North West Bay River catchment in Tasmania. Recent local advocacy has sought a reduction in the proportion of the river that is diverted into the City of Hobart's water supply in order to benefit stakeholders downstream of the diversion intakes. Four future scenarios are developed that present a range of possible actions associated with the water management regime. Criteria weights are inserted into the MCE framework based on responses to a mail survey.

The potential changes in ecosystem services are evaluated across the scenarios over a 10-year timeframe. Implementing a range of integrated catchment management measures will have the greatest positive change to the values provided by the North West Bay River. Maintaining the current management regime is likely to lead to an

overall decline in ecosystem service values. Any potential improvements in ecosystem service values are dependent on reducing the uncertainty involved in impact prediction and selecting cost-effective management scenarios. The decision framework provides a number of advantages when compared with alternative valuation approaches through its ability to integrate scientific assessment with valuation techniques, and provide opportunities for knowledge building and stakeholder engagement.

Acknowledgments

Writing a PhD thesis is a long journey and many people have supported me along the way. I would firstly like to thank my primary supervisor, Michael Lockwood, whose patience, knowledge and organisation is remarkable. Michael provided great wisdom particularly in the areas of natural resource management and ecosystem valuation. Both these topics involve a large body of knowledge so his helpful hints and guidance in the right direction were extremely helpful.

My co-supervisor, Kevin Kiernan, provided extensive knowledge and practical support for this thesis. His passion for the environment and considerable knowledge of the North West Bay River catchment (what I perceive to be his 'outdoor playground') was a true blessing. Particular mention must be made to the time and efforts Kevin put in to understand some of the topics covered in this thesis which were outside his main areas of expertise.

This thesis involved a significant number of informal and formal discussions with people across a range of disciplines and backgrounds. I am extremely grateful for the contributions made by members of the expert panel, and to DPIW, Hobart Water and Kingborough Council who were happy to provide me with a range of information for the North West Bay River catchment. In particular, Martin Read, Marcus Higgs and Andrew Truscott were extremely helpful with my endeavours, and have each contributed an incredible amount of work towards enhancing this unique river catchment for the benefits to the wider community.

My heartfelt thanks must go to more than 600 people across the greater Hobart region who responded to the mail survey. A special financial contribution to the survey was made by Hobart Water, in addition to support I received from the School of Geography and Environmental Studies. Peter Ashley provided active support to the development of the survey given that he was working on a similar project.

The University of Tasmania and the School of Geography and Environmental Studies provided me the perfect location and academic group to foster my thoughts, support my findings and offer encouragement for this work. I am extremely grateful to Hydro Tasmania for selecting me as the inaugural recipient of the Dr Sergio Guidici Research

Scholarship. It was an honour to be the recipient of an award that honours the contribution to society made by such an incredibly talented and passionate individual.

Finally, my family have provided me with the very best foundations and support for this work. My beautiful partner in life, Simone, inspires me everyday with her generosity, wisdom, care and understanding, despite the large body of water (the Tasman Sea) that kept us apart for long periods. Simone's extravagant love was more than enough to provide me with the courage and enthusiasm to write the words that follow.

Table of Contents

DECLARATIONII

ABSTRACT..... III

ACKNOWLEDGMENTSV

TABLE OF CONTENTSVII

LIST OF FIGURESX

LIST OF TABLES XI

CHAPTER 1 INTRODUCTION.....1

1.1 RESEARCH PROBLEM..... 1

1.2 RESEARCH QUESTION AND OBJECTIVES4

1.3 METHODOLOGICAL APPROACH5

1.4 ORGANISATION OF THE THESIS.....6

SECTION I: CONCEPTUAL FOUNDATIONS9

CHAPTER 2 DECISION-MAKING FOR NATURAL RESOURCE MANAGEMENT 10

2.1 INTRODUCTION..... 10

2.2 INTEGRATED SOCIO-ECOLOGICAL SYSTEMS 10

2.3 APPROACHES TO NATURAL RESOURCE MANAGEMENT 17

2.4 CRITERIA FOR EFFECTIVE NATURAL RESOURCE DECISION-MAKING27

2.5 SUMMARY32

CHAPTER 3 ECOSYSTEM SERVICES.....33

3.1 INTRODUCTION.....33

3.2 DEVELOPMENT OF THE ECOSYSTEM SERVICES CONCEPT33

3.3 DISTINGUISHING ECOSYSTEM SERVICES36

3.4 ECOSYSTEM SERVICE VALUES44

3.5 SUMMARY50

CHAPTER 4 ECOSYSTEM VALUATION.....52

4.1 INTRODUCTION.....52

4.2 ECONOMIC VALUATION.....53

4.3 SOCIAL PSYCHOLOGY METHODS.....61

4.4 MULTI-CRITERIA EVALUATION62

4.5 DELIBERATIVE VALUATION.....65

4.6 ISSUES FOR ECOSYSTEM SERVICE VALUATION.....68

4.7 SUMMARY73

SECTION II: METHODS AND CASE STUDY75

CHAPTER 5 A DECISION SUPPORT FRAMEWORK FOR EVALUATING CHANGE IN ECOSYSTEM SERVICES76

5.1 INTRODUCTION.....76

5.2 MIXED METHOD APPROACHES76

5.3 THE MULTI-CRITERIA EVALUATION FRAMEWORK.....78

5.4 MCE AGGREGATION85

5.5 COST-EFFECTIVENESS ANALYSIS85

5.6 SUMMARY86

CHAPTER 6 CASE STUDY OF THE NORTH WEST BAY RIVER CATCHMENT, TASMANIA 87

6.1 INTRODUCTION.....87

6.2 CASE STUDIES87

6.3 CATCHMENT DESCRIPTION92

6.4 CURRENT USES OF THE NORTH WEST BAY RIVER.....102

6.5 FINDING THE BALANCE BETWEEN WATER SUPPLY AND OTHER ECOSYSTEM SERVICES.....107

6.6 SUMMARY118

CHAPTER 7 THE EXPERT PANEL PROCESS119

7.1 INTRODUCTION.....119

7.2 EXPERT PANELS119

7.3 IMPLEMENTATION OF THE EXPERT PANEL125

7.4 SUMMARY129

CHAPTER 8 SURVEY DESIGN AND IMPLEMENTATION.....131

8.1 INTRODUCTION.....131

8.2 DEVELOPMENT OF THE DRAFT QUESTIONNAIRE.....131

8.3 SURVEY PRE-TESTING137

8.4 IMPLEMENTATION AND RESPONSE TO THE MAIL SURVEY139

8.5 SUMMARY145

SECTION III: RESULTS146

CHAPTER 9 AN ECOSYSTEM SERVICES MODEL FOR THE NORTH WEST BAY RIVER147

9.1 INTRODUCTION.....147

9.2 DEVELOPMENT OF A CONCEPTUAL MODEL147

9.3 ANALYSIS OF THE PRELIMINARY MODEL152

9.4 FINAL ECOSYSTEM SERVICES CONCEPTUAL MODEL.....161

9.5 SUMMARY166

CHAPTER 10 DEFINING FUTURE SCENARIOS AND IMPACTS.....167

10.1 INTRODUCTION 167

10.2 SCENARIO DEVELOPMENT 167

10.3 INITIAL PHASE 168

10.4 PRELIMINARY SCENARIOS 171

10.5 FINAL SCENARIOS..... 176

10.6 IDENTIFYING POTENTIAL IMPACTS 179

10.7 FINANCIAL INVESTMENT ENTAILED IN THE SCENARIOS 206

10.8 SUMMARY 211

CHAPTER 11 SURVEY RESULTS.....212

11.1 INTRODUCTION 212

11.2 THE RESPONDENTS..... 212

11.3 IMPORTANCE RATINGS FOR NORTH WEST BAY RIVER VALUES 221

11.4 VALUES AND STAKEHOLDERS 226

11.5 DEVELOPMENT OF MULTI-CRITERIA WEIGHTS 232

11.6 SUMMARY 235

CHAPTER 12 RESULTS OF THE MULTI-CRITERIA EVALUATION236

12.1 INTRODUCTION 236

12.2 AGGREGATION OF RESULTS..... 236

12.3 STAKEHOLDER VALUES IN THE MULTI-CRITERIA EVALUATION..... 242

12.4 SENSITIVITY ANALYSIS 244

12.5 COST-EFFECTIVENESS ANALYSIS OF MULTI-CRITERIA OUTCOMES 245

12.6 SUMMARY 247

SECTION IV: DISCUSSION & CONCLUSIONS248

CHAPTER 13 DISCUSSION.....249

13.1 INTRODUCTION 249

13.2 ECOSYSTEM SERVICES TYPOLOGIES..... 249

13.3 CRITICAL ASSESSMENT OF THE INTEGRATED DECISION TOOL 251

13.4 OUTCOMES FOR THE NORTH WEST BAY RIVER CASE 258

13.5 SUMMARY 263

CHAPTER 14 CONCLUSIONS.....264

REFERENCES.....269

APPENDICES.....287

APPENDIX 1: EXPERT PANEL QUESTIONNAIRES 288

APPENDIX 2: MAIL SURVEY PACKAGE..... 316

APPENDIX 3: MAIL SURVEY POSTCARD REMINDER 328

APPENDIX 4: CRITERIA WEIGHTS FOR MAJOR STAKEHOLDER GROUPS	329
---	-----

List of Figures

FIGURE 1: AN EXPANDED MODEL OF THE ECOLOGICAL-ECONOMIC SYSTEM.....	16
FIGURE 2: THE LADDER OF CITIZEN PARTICIPATION	25
FIGURE 3: DISTINGUISHING BETWEEN ECOSYSTEM GOODS AND SERVICES	38
FIGURE 4: THE TOTAL ECONOMIC VALUE FRAMEWORK	46
FIGURE 5: METHODOLOGY IN THE AUSTRALIAN ECOSYSTEM SERVICES PROJECT.....	73
FIGURE 6: METHODOLOGICAL FLOW DIAGRAM	81
FIGURE 7: LOCATION OF THE NORTH WEST BAY RIVER CATCHMENT, TASMANIA	92
FIGURE 8: MAP OF THE NORTH WEST BAY RIVER CATCHMENT	93
FIGURE 9: NWBR MONTHLY MEDIAN FLOWS AT MARGATE WEIR IN MEGALITRES PER DAY	97
FIGURE 10: HOBART MOUNTAIN WATER SUPPLY CATCHMENT AREA	106
FIGURE 11: ANNUAL WATER TAKES FROM THE NWBR CATCHMENT 1978-2005.....	112
FIGURE 12: AVERAGE MONTHLY WATER TAKES FROM THE HOBART MOUNTAIN SUPPLY AREA 2002-06.....	113
FIGURE 13: ECOSYSTEM SERVICES CLASSIFICATION FOR THE NORTH WEST BAY RIVER.....	151
FIGURE 14: EXPANSION OF CATCHMENT BOUNDARY TO INCLUDE NORTHERN PART OF NORTH WEST BAY	154
FIGURE 15: ECOSYSTEM SERVICES CONCEPTUAL MODEL FOR THE NORTH WEST BAY RIVER CATCHMENT	163
FIGURE 16: ECOLOGICAL SERVICE DEFINITIONS FOR THE NORTH WEST BAY RIVER CONCEPTUAL MODEL	164
FIGURE 17: PROVISIONING AND CULTURAL SERVICES FOR THE NORTH WEST BAY RIVER	165
FIGURE 18: 95 PERCENTILE FLOWS AT MARGATE WEIR ACROSS ALL SCENARIOS	185
FIGURE 19: HOBART WATER TAKES AND BETTS ROAD FLOWS IN THE <i>FLOW THRESHOLD</i> SCENARIO	186
FIGURE 20: HOBART WATER TAKES AND BETTS ROAD FLOWS IN THE <i>INTEGRATED CATCHMENT MANAGEMENT</i> SCENARIO.....	187
FIGURE 21: VISITOR FREQUENCY TO NORTH WEST BAY RIVER DURING PAST YEAR.....	217
FIGURE 22: VISITOR PERCENTAGES ACCORDING TO RESIDENT LOCATION	218
FIGURE 23: FREQUENCY OF RESPONDENTS INVOLVED IN ACTIVITIES IN RIVER ENVIRONMENT.....	219
FIGURE 24: FREQUENCY OF RESPONDENTS WITH ALTERNATIVE WATER SOURCES.....	220
FIGURE 25: VALUE DOMAIN IMPORTANCE RATINGS FOR CATCHMENT AND NON-CATCHMENT RESIDENTS	229
FIGURE 26: VALUE DOMAIN IMPORTANCE RATINGS FOR TYPES OF RIVER VISITORS.....	231
FIGURE 27: VALUE DOMAIN IMPORTANCE RATINGS FOR TYPES OF WATER SUPPLY USERS	232
FIGURE 28: OVERALL CHANGE IN TOTAL ECOSYSTEM SERVICE VALUES ACROSS EACH SCENARIO.....	239
FIGURE 29: AVERAGE PERCENTAGE CHANGE FOR VALUE DOMAINS	241
FIGURE 30: AVERAGE PERCENTAGE CHANGE IN ECOLOGICAL SERVICES ACROSS SCENARIOS.....	242

List of Tables

TABLE 1: CRITERIA FOR EFFECTIVE DECISION-MAKING IN NATURAL RESOURCE MANAGEMENT28

TABLE 2: ECOSYSTEM FUNCTIONS AND SERVICES OF ECOSYSTEMS39

TABLE 3: DESCRIPTIVE CLASSIFICATIONS OF ECOSYSTEM SERVICES41

TABLE 4: APPROACHES TO ECOSYSTEM VALUATION53

TABLE 5: OVERVIEW OF ECONOMIC VALUATION METHODS58

TABLE 6: AN OVERVIEW OF NON-ECONOMIC VALUATION TECHNIQUES67

TABLE 7: EXAMPLE OF A MULTI-CRITERIA EVALUATION EFFECTS TABLE80

TABLE 8: ECOSYSTEM SERVICE VALUE CHANGE SCALE84

TABLE 9: SUMMARY OF INFORMATION AVAILABLE FOR NORTH WEST BAY RIVER CATCHMENT 111

TABLE 10: COMPARISON BETWEEN NATURAL AND RESTRICTED FLOWS IN UPPER REACHES 114

TABLE 11: ESTIMATED FLOWS AT BETTS ROAD BRIDGE 115

TABLE 12: FLOWS FOR RISK CATEGORIES FOR BETTS ROAD BRIDGE..... 116

TABLE 13: FLOWS FOR RISK CATEGORIES BELOW MARGATE WEIR 117

TABLE 14: RE-ASSESSMENT OF RISK LEVEL FLOWS AT BETTS ROAD BRIDGE..... 118

TABLE 15: RESPONSE RATES FOR THE NORTH WEST BAY RIVER SURVEY 143

TABLE 16: RESPONSE RATES ACROSS SURVEY GROUPS 144

TABLE 17: FREQUENCY OF CATCHMENT MANAGEMENT THEMES EXPRESSED BY EXPERT PANEL 170

TABLE 18: IMPACT ON ECOLOGICAL SERVICES OF FUTURE MANAGEMENT SCENARIOS..... 181

TABLE 19: LOWER RANGE ESTIMATES OF VALUE CHANGES FOR THE *STATUS QUO* SCENARIO 194

TABLE 20: UPPER RANGE ESTIMATES OF VALUE CHANGES FOR THE *STATUS QUO* SCENARIO..... 195

TABLE 21: LOWER RANGE ESTIMATES OF VALUE CHANGES FOR THE *FLOW THRESHOLD* SCENARIO 196

TABLE 22: UPPER RANGE ESTIMATES OF VALUE CHANGES FOR THE *FLOW THRESHOLD* SCENARIO..... 197

TABLE 23: LOWER RANGE ESTIMATES OF VALUE CHANGES FOR THE *INTEGRATED CATCHMENT*
MANAGEMENT SCENARIO..... 198

TABLE 24: UPPER RANGE ESTIMATES OF VALUE CHANGES FOR THE *INTEGRATED CATCHMENT MANAGEMENT*
SCENARIO 199

TABLE 25: LOWER RANGE ESTIMATES OF VALUE CHANGES FOR THE *SUMMER FLOWS* SCENARIO200

TABLE 26: UPPER RANGE ESTIMATES OF VALUE CHANGES FOR THE *SUMMER FLOWS* SCENARIO201

TABLE 27: PREDICTED ESTIMATE OF THE FINANCIAL INVESTMENT REQUIRED FOR EACH SCENARIO (2008-
2017)210

TABLE 28: COMPARISON OF THE SAMPLE AND POPULATION FREQUENCIES FOR GENDER213

TABLE 29: COMPARISON OF THE SAMPLE AND POPULATION FREQUENCIES FOR AGE CATEGORIES214

TABLE 30: WORK STATUS FOR RESPONDENTS.....215

TABLE 31: HIGHEST EDUCATIONAL LEVEL FOR RESPONDENTS.....215

TABLE 32: HOUSEHOLD OWNERSHIP216

TABLE 33: VISITOR FREQUENCIES BETWEEN CATCHMENT AND NON-CATCHMENT GROUPS.....217

TABLE 34: PROPORTION OF RESPONDENTS CONNECTED TO GREATER HOBART WATER SUPPLY.....219

TABLE 35: OVERALL VALUE IMPORTANCE RATINGS.....222

TABLE 36: AVERAGE IMPORTANCE RATINGS FOR VALUE DOMAINS	223
TABLE 37: FACTOR LOADINGS FOR VALUE ITEMS.....	225
TABLE 38: SURVEY AND STAKEHOLDER GROUPS.....	226
TABLE 39: VALUE IMPORTANCE RATINGS ACROSS SURVEY GROUPS.....	228
TABLE 40: OVERALL CRITERIA WEIGHTS.....	234
TABLE 41: EXAMPLE OF AN ECOSYSTEM SERVICE VALUE IMPACT MATRIX FOR THE <i>SUMMER FLOWS</i> SCENARIO	238
TABLE 42: AVERAGE PERCENTAGE CHANGE IN TOTAL ECOSYSTEM SERVICE VALUES FOR STAKEHOLDER GROUPS.....	243
TABLE 43: COST-EFFECTIVENESS COMPARISON FOR EACH SCENARIO OVER 10-YEAR PERIOD (2008-2017)	246